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Rethinking Existing Approaches to Water Security in Remote Communities: An Analysis of Two Drinking Water Systems in Nunatsiavut, Labrador, Canada

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ABSTRACT: This paper introduces an approach to understanding water security in remote communities that emphasises drinking water access, availability, quality, and preference, presenting exploratory findings from Rigolet and Nain, located within the Inuit Settlement Region of Nunatsiavut, eastern Subarctic Canada. Individual and household interviews numbering 121 and 13 key informant interviews were conducted in 2009 and 2010. Interview findings were analysed with results from participant observation, a review of municipal water system records and secondary sources. Results reveal restricted access to a sufficient quantity of desirable, clean, drinking water for some residents, despite the existence of municipal water systems in both communities. Drinking water sources available to residents include tap water, store-bought water and water gathered from running streams, lakes and ice melt. Drinking water preferences and risk perceptions indicate these sources are regarded as distinct by study participants. 81% of respondents prefer water gathered from the land over other alternatives and 22% primarily consume this source while in the community. These findings must be understood within the context of drinking water system attributes and the geographies of people and place characterising the region.

KEYWORDS: Inuit, community drinking water system, perceptions of drinking water, drinking water preferences, water security, Arctic

INTRODUCTION

Water security is an emerging area of research in Arctic Canada, inspired in part by questions concerning the implications of climate variability and change on arctic freshwater ecosystems. These questions arose from observations of biophysical changes in freshwater ecosystems shared by arctic residents and documented through empirical studies by researchers in the scientific community. Findings from this body of literature describe changes in river discharge, run-off, seasonal precipitation, and water levels of freshwater bodies across the Arctic.

Small declines in discharge of North American rivers flowing into the Arctic Ocean were documented by Déry and Wood (2005), while Déry et al. (2005) noted significant declines in discharges of 36 of the 42 rivers draining into Hudson Bay, James Bay and Ungava Bay from 1964 to 2000. Analysis of US Geological Survey data from nine stream monitoring stations in central and northern Alaska (each with about fifty years of data) by Hinzman et al. (2005) revealed increasing trends in run-off within glacialfed basins and decreasing trends in those river basins lacking large glaciers. Yoshikawa and Hinzman (2003) found a reduction in surface area of 22 of the 24 thermokarst ponds from 1950 to 2000 within discontinuous permafrost zones on the Seward Peninsula in Alaska. Reflecting on similar findings from a study conducted in Siberia, Smith et al. (2005) warned that "the ultimate effect of continuous climate warming on high-latitude, permafrost-controlled lakes and wetlands may well be their widespread disappearance".

In eastern Subarctic Canada, residents across Nunatsiavut have noted similar changes in the availability of fresh water and lowering levels of surface water bodies (Communities of Labrador et al., 2005). In addition, Huntington et al. (2005) noted observations of gradually lowering levels of surface water bodies in Baker Lake, Nunavut (in the eastern Canadian Arctic), commencing in the 1960s and accelerating since the 1990s. Similar changes have also been documented in Kugaaruk and Repulse Bay, Nunavut (Communities of Arctic Bay et al., 2005) and Ulukhaktok, Inuvialuit Settlement Region (ISR; located in the western Canadian Arctic; Communities of the Aklavik et al., 2005). Such observations were further discussed by Pokiak (2005) in describing the recession of two lakes outside of Tuktoyaktuk, ISR, where whitefish were once abundant, and low water levels in the lake feeding the municipal water system (MWS). In response to the significant drop in water levels and the subsequent loss of fish, communities of the ISR have dredged fish channels to encourage future fish populations (Nickels et al., 2005). The communities of Ivujivik, Puvirnituq, and Kangiqsujuaq, Nunavik (located in northern Quebec, in eastern Subarctic Canada) noted declining annual rainfall and snowfall totals and lower water levels of lakes and rivers in their region leading to increases in the turbidity of water. Residents expressed concern regarding the quality of drinking water gathered by the community as a consequence of these trends (Communities of Ivujivik et al., 2005).

The biophysical changes experienced and described in these studies are potentially harmful to residents who rely on these waterways to provide essential sources of food and drinking water (Berner et al., 2005; White et al., 2007). These trends may continue in the future as climate variability and change modify the spatial and temporal distribution of fresh water and alter freshwater ecosystems in the Arctic (Wrona et al., 2006; Bates et al., 2008). Despite an acknowledgement of these concerns in the literature, few studies have identified the implications of current and future freshwater trends on the well-being[1] of Arctic residents, or their ability to secure adequate sources of food and water. There is further need to understand the consumption practices of drinking water and perceptions in Arctic communities. As stated by Alessa et al. (2008), "documenting and characterizing the dynamics of sociocultural perceptions of freshwater is critical to anticipating how communities will respond to changing hydrological regimes". To inform future considerations of water security, a baseline understanding of the characteristics of the drinking water system, the perceptions of drinking water, drinking water preferences, and factors contributing to the current water security of residents is needed.

Through the support of findings from a field study conducted in the self-governed Inuit settlement region of Nunatsiavut, Labrador, this paper introduces an approach to understanding water security in remote communities that is grounded in the perspectives of residents and the attributes of community drinking water systems. Within this study, 'drinking water' includes all water consumed for drinking purposes and does not include water used for cooking, bathing or other uses. Water security is conceptualised as a function of water access, availability, quality and preference. The consideration of all four of these dimensions is intended to create space for consumption practices and preferences of drinking water that may differ from those currently assumed by the norms of water security discourse. The paper goes on to present exploratory findings that identify factors contributing to water security in

[1] While definitions of the term 'well-being' are becoming increasingly precise in the literature, the use of the term here is simply meant to imply general welfare.

the communities of Rigolet and Nain, Nunatsiavut, highlighting preferences and perceptions of drinking water and current challenges in both communities. The paper concludes by drawing connections between these findings and those in similar studies in other Arctic communities and calls for further consideration of the implications of climate variability and change on water security in the Arctic.

(RE)CONCEPTUALISING WATER SECURITY IN REMOTE COMMUNITIES

This paper presents a new definition of water security as a function of four variables: access, availability, quality, and preference . This definition is informed by recent discussions within the Arctic food security literature which emphasises the importance of considering food preference as a component of food security (e.g. Kuhnlein et al., 2004; Lambden et al., 2007; Loring and Gerlach, 2009; Ford, 2009; Goldhar and Ford, 2010; Goldhar et al., 2010). The authors argue that food preference is intimately linked with the experience of food (in)security and should be regarded as an integral dimension of food 'quality' and thus of food security (van Esterik, 1999; Gregory et al., 2005; Lambden et al., 2007; Ford, 2009; Loring and Gerlach, 2009; Goldhar and Ford, 2010; Goldhar et al., 2010). The Food and Agriculture Organization of the United Nations (FAO) defines food security as a state where "all people, at all times, have physical and economic access to sufficient, safe, and nutritious food to meet their dietary needs and food *preferences* for an active and healthy life" (FAO, 1996, emphasis added).

While there is substantial literature that investigates preferences and perceptions of drinking water (e.g. Auslander and Langlois, 1993; Levallois et al., 1999; Anadu and Harding, 2000; Doria, 2006; Jones et al., 2006, 2007; Burlingame and Mackey, 2007), these considerations are not incorporated into mainstream definitions of water security. Approaches to understanding water security commonly emphasise elements of access, availability and safety. An often-cited definition presented at the Second World Water Forum at The Hague in 2000, states: "water security means ensuring that freshwater, coastal, and related ecosystems are protected and improved; that sustainable development and political stability are promoted; that every person has access to adequate safe water at an affordable cost to lead a healthy and productive life; and that the vulnerable are protected from the risks of water-related hazards" (World Water Council, 2000). The aspects of this definition that concern human drinking water highlight elements of access, safety, cost, health and productivity.

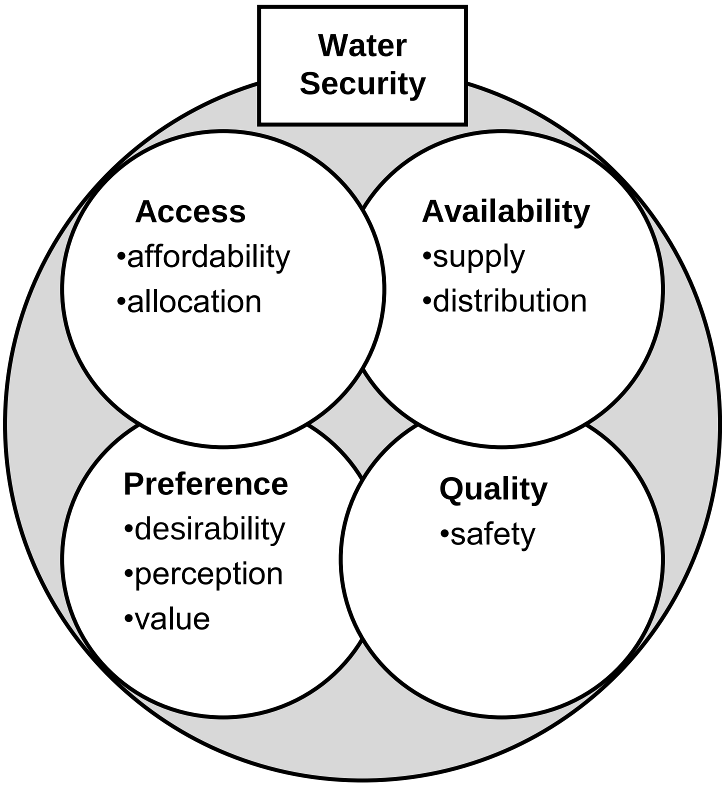
Scale is an important consideration in the conceptualisation of water security. While the definition introduced above is intentionally inclusive of multiple scales of analysis, discussing the needs of ecosystems as well as individuals, definitions of water security can range in relevance from individuals and communities (as discussed in this study, see also Alessa, Kliskey, Busey et al., 2008; Alessa et al., 2008; Marino et al., 2009; Norman et al., 2013), ecosystems and watersheds (Dunn and Bakker, 2009; 2011; Bakker, 2012; Norman et al., 2010; 2011) or countries and regions (White et al., 2007; Vörösmarty et al., 2010; Zeitoun et al., 2010).

Within what Cook and Bakker (2012) have identified as the 'human needs approach' to water security, it is not uncommon to frame the concept as a subset of food security. These approaches typically emphasise the need for sufficient water to ensure agricultural food production and avoid food scarcity in arid regions (Biswas, 1999; FAO, 2000; Liu et al., 2007; Falkenmark, 2010) and thus do not draw on considerations of food preference. Hadley and Wutich (2009) push these connections further by identifying a need for measurements of water and food security that account for the biocultural nature of both food and water needs, augmenting existing biophysical considerations. While not addressing water preferences, Hadley and Wutich argue for "locally-appropriate tools to measure the experiential dimensions of food and water insecurity" (2009: 451), thus recognising the diversity of water needs and contexts that may shape water security.

The concept of water security presented in this study is founded on the notion of a drinking water system (DWS), and is drawn from the idea of a 'food system' that underlies concepts of food security described by Gregory et al. (2005)[2] and later used by Ford (2009). A DWS comprises dynamic interactions between and within biogeophysical and human environments that result in the collection, distribution and consumption of water. While the notion is intentionally anthropocentric, approaching water through a human needs-based lens and specifically addressing human consumption of drinking water, the DWS is regarded as a social-ecological system or a human-environment system that encompasses the synergistic relationship between human and environmental components. This concept closely relates to the notion of a 'human-hydrological system' adopted by Alessa, Kliskey, Busey et al. (2008) and is influenced by the social-ecological systems literature (e.g. Berkes and Folke, 1998; Berkes and Jolly, 2001) and resilience theory (e.g. Holling, 1973).

A DWS encompasses components of: i) access to water (including elements of affordability and allocation); ii) availability of water (with elements including supply and distribution); iii) quality of water (including elements of safety); and iv) preference of water (including elements of desirability, perception, and value). The primary contribution of this conceptualisation within existing water security approaches is the inclusion of preference, illustrated through elements of desirability, perception and value. Use of the DWS concept grounds water security understandings within the attributes of a community and locality. 'Water security' signifies an ability to access a sufficient quantity of *desirable*, clean drinking water in a manner that maintains human dignity. Water insecurity exists when the DWS is stressed, compromising one or several components (Figure 1).

Figure 1. Dimensions of water security.



[2] Gregory et al. (2005) describe a food system as a set of "dynamic interactions between and within biogeophysical and human environments which result in the production, processing, distribution, preparation, and consumption of food".

Stresses influencing the DWS may include a variety of factors, some of whose examples are presented here. Water availability can be diminished by biophysical changes in a watershed or market changes and other economic factors that control the supply of bottled water for sale in a community. Seasonal changes such as spring run-off can diminish the quality of freshwater sources, in addition to possible industrial pollutants and variability in the performance of water treatment facilities. The accessibility of drinking water is influenced by community planning decisions and household economic factors that may determine whether or not a home is connected to the local tap water supply or whether a family has a vehicle and the fuel necessary to travel to collect drinking water from running streams. In addition, through the lens of water security presented above, limited access to preferred water sources alone implies a degree of water insecurity. Water security can be threatened despite one's ability to acquire a sufficient quantity of clean water that would meet daily health requirements. The significant role of water preferences in shaping community water security was clearly highlighted by residents of Nunatsiavut, where this study was conducted.

NUNATSIAVUT CASE STUDY: STUDY AREA

Nunatsiavut is located on the northern coast of Labrador and covers roughly 15,800 km^2 (Figure 2). The region lies within the taiga-tundra transition ecozone, characterised by rocky barrens and low-lying vegetation typical of tundra environments, and a sporadic treeline framing forests of thick spruce, birch, poplar and aspen (Ames, 1977). The cold Labrador current draws Arctic waters down the coast of Labrador and lowers temperatures below those experienced at similar latitudes inland in Canada (Banfield, 1981). The region is classified as Dfc or 'Subarctic' within the Köppen climate classification system and is characterised by short, cool summers and long, cold winters (Christopherson and Byrne, 2006).

Nunatsiavut achieved self-governance in 2005 following the establishment of the Labrador Inuit Land Claims Agreement after more than three decades of negotiations (Nunatsiavut Government, 2011). The five communities located in Nunatsiavut are predominantly Inuit (91%)[3] and range in population size from 206 in Postville to 1190 in Nain (Table 1). Communities are not connected by roads, though residents travel frequently by motorboat along the coast in the ice-free season and by snowmobile in winter. Movement in and out of the locality of the settlement is fluid and frequent as residents rely on surrounding environs for firewood and drinking water, and commonly make trips of varying length to cabins to hunt, fish, or participate in other land-based activities. These practices have evolved from generations of movement between seasonal camps along the coast and inland sites up major waterways during pre-settlement periods (Fitzhugh, 1977).

Small, weather-dependent aircraft (mostly de Havilland twin otters) service the communities by transporting goods, residents and visitors. During summer months a ferry services the coast, providing shipping and transportation opportunities at lower cost than by air. As is characteristic of 'diverse economies' or 'mixed-subsistence/cash' economies, residents are engaged to varying degrees within the capitalist wage-based system. Income earned through waged employment and social transfer payments is supplemented by the procurement of traditional foods and goods harvested from the land and sea. The subsistence and cash economies are so closely intertwined in Labrador, as they are in many regions of the Arctic, that boundaries differentiating the two are largely superficial.[4] As discussed by Wenzel (2000) for small Inuit communities in Nunavut, harvesting activities are conducted under

[3] For a detailed discussion of the complex ethno-history of the region see Brice-Bennett et al. (1977), Kennedy (1985), and Plaice (2009).

[4] For a similar point regarding Greenland see Dahl (1989).

conditions in which money has become as fully a part of the subsistence environment as food or other natural raw materials.

Figure 2. Nunatsiavut, Labrador, Canada is indicated by the shaded regions on this map. It comprises Labrador Inuit Settlement Areas and Labrador Inuit Lands.

Table 1. Descriptive socio-economic statistics for Nunatsiavut communities.

Characteristic	Nain	Hopedale	Rigolet	Makkovik	Postville	Nunatsiavut	Newfoundland and Labrador
Population (2011)	1190[a]	556	305	361	206	2618	514,536
Population change 2006-2011 (%)	14.9	4.9	13.8	-0.3	-5.9	5.48	1.8
Median income after tax ($ Cdn.; 15yrs+)*	18,048	no data	16,416	18,176	no data	no data	18,149
Average household size*	3.7	3.5	3	3.1	3.1	3.3	2.5
Mother tongue English (%)	63	83	100	93	100	87.8	98
Population identifying as Aboriginal (%)*	92	no data	94	88	91	91	5
Unemployment rate*	27.9	no data	31.8	37.1	30	31.7	18.6

[a] Census data are commonly flawed in Nunatsiavut. The Inuit Community Government of Nain reported an underrepresentation of population size by roughly 10% in the 2006 census (NICG, personal communication, September 2011).

Sources*:* Statistics Canada, *2007, 2012.

METHODS

Data were collected for this study from spring 2009 to winter 2011 through a variety of methods. In Rigolet, the project was developed during a series of meetings with residents and community leaders in June 2009. Feedback and suggestions of residents were incorporated into the research design, including the timing of fieldwork, methods of data collection, possible language considerations, and the interview guide. The Nain portion of the study was developed in partnership with the Nain Inuit Community Government (NICG) and the Nunatsiavut Government in winter 2009. Research in both Nain and Rigolet was conducted through the support of a research assistant from the community; in Nain two interpreters joined the research team.

In September 2009, semi-structured household interviews numbering 59 (88% response) were conducted in Rigolet, followed by 13 key informant interviews in each Nunatsiavut community (Postville, Makkovik, Hopedale and Nain). Key informant interviews were conducted with representatives of each Inuit Community Government, municipal water workers, health care workers, a cabinet minister in the Nunatsiavut Government, and other community leaders. In September 2010, semi-structured household interviews numbering 32 (64% response) were conducted in Nain. All interviews in both communities were conducted with adults (age 18 and over) and commenced with a short, structured component asking the perspectives of a single household representative. The structured component of the interview contained questions about preferences and perceptions of drinking water, while semi-structured questions concerned the performance of the municipal water system, consumption practices of drinking water, and the general aesthetic characteristics of tap water, store-bought water, and water collected from the land.

As the population of Rigolet is much smaller than in Nain it was possible to include all 101 households in the interview sample, whereas a portion of homes was selected in Nain. Attempts were made to spatially balance the Nain household sample, ensuring selected households were evenly distributed throughout the community and throughout the water distribution system. This was done to minimise possible bias stemming from diverse tap water attributes and household proximity to drinking water sources. All homes were numbered on a community map that was divided into five quadrants. Ten homes were randomly selected in each quadrant using a random number generator (totalling a sample of 50 households).

The majority of interviews took place in participants' homes and were conducted in English, with Inuktitut translation available. Data analysis was an iterative process that commenced in the field. Interview data were transcribed, coded manually through a process inspired by 'constructivist grounded theory' (Charmaz, 2003, 2006; Bryant and Charmaz, 2007) and analysed in conjunction with water reports, gathered in the communities, and field notes from participant observation. The study was approved by the Nunatsiavut Research Advisory Committee and by the Interdisciplinary Committee on Ethics in Human Research at Memorial University. When interview quotes are used to illustrate study results, respondents are identified by pseudonyms.

Sample characteristics

The short, structured component of each interview was completed by a volunteer member of the household immediately before the semi-structured interview. During this structured component the volunteer was requested to respond to a series of questions regarding their personal preferences and perceptions of drinking water. Of the population of Rigolet, 33% participated in the structured interviews, while 3% participated in Nain. Household members participating in the semi-structured interviews that followed this structured component responded collectively and included all interested adult residents of the home (participation up to four members). No social or demographic characteristics were collected from household respondents as no comparable census data were available at the household scale for study communities. Rather, as noted earlier, care was taken when randomly selecting the Nain sample to spatially balance the sample to ensure that the locations of respondents' homes varied in proximity to sources of drinking water available in the community, and were evenly spread throughout the municipal water distribution system.

Women were overrepresented within the structured portion of the interviews in both Nain and Rigolet (by 10% in Rigolet and 17% in Nain; Table 2). The participation of women in this portion of the study may have been encouraged by the presence of a female research team, and may have been additionally influenced by the timing of research and gender roles in the community. While interviews were conducted during evenings and weekends, and occasional appointments were made with respondents in advance of interviews, the majority of participants were approached during door-to-door visits at their homes during the day. The higher proportion of women working as 'homemakers'

Table 2. Structured interview sample characteristics in Rigolet and Nain relative to census data.

	Variable	Rigolet sample[a] (%)	Rigolet census data (%)	Nain sample[b] (%)	Nain census data (%)
Gender	Male	42	52	33	52
	Female	58	48	67	48
Age	15-29	6	28	17	29
	30-44	33	21	27	21
	45-59	44	23	33	19
	60-74	10	10	20	7
	75+	8	2	3	2
Occupation*	Unemployment rate[a]	9	31.8	9	27.9
	Part-time worker	7		6	
	Full-time worker	46		46	
	Casual or seasonal	17		9	
	Other[b]	21		30	
Miscellaneous	Years in the community (average)	35.7		38.6	
	Weeks per year spent on the land (average)	5.8		2.75	
Household	Adults (18 years and over) in home (average)	2.1		2.3	
	Children in home (average)	0.7		1	

Source*:* Statistics Canada, *2007, 2012.

Notes:

n=89 in all categories with the exception of occupation where n=87.

n=33 in all categories with the exception of age where n=30.

[a] Includes all participants presently seeking employment. Census data represent the unemployment rate in the community.

[b] Includes all participants not currently employed and not presently seeking waged work. This category encompasses subsistence hunters and fishers, homemakers, elders, etc.

relative to men in both communities and the disproportionate participation of men in land-based activities and employment outside the community may have contributed to the likelihood of women being home during the day. Similar factors may account for the overrepresentation of older age cohorts who no longer work and are more commonly available at home during the day. Adults over the age of 60 were overrepresented by 7% in Rigolet and 13% in Nain.

Both Nain and Rigolet have a significant portion of young people underrepresented in this study. The youngest age category (15-29 years) was underrepresented by 22% in Rigolet and 12% in Nain. The study intentionally targeted adults (age 18 and over); consequently, the age category of 15 to 29 years used within the census data is not directly comparable to the sample characteristics of the study. This may account for part of the underrepresentation of this age grouping in the sample, though it is likely that generational expectations played a stronger contributing role. The customary role of elders and older generations as teachers and guides in the community may have limited the volunteerism of young adults for the structured interview when in the presence of an older household member. Descriptive statistics used to illustrate structured interview findings were analysed and are presented in conjunction with findings from semi-structured household interviews, key-informant interviews, participant observation and secondary sources.

WATER SECURITY IN NUNATSIAVUT: DWS ATTRIBUTES IN NAIN AND RIGOLET

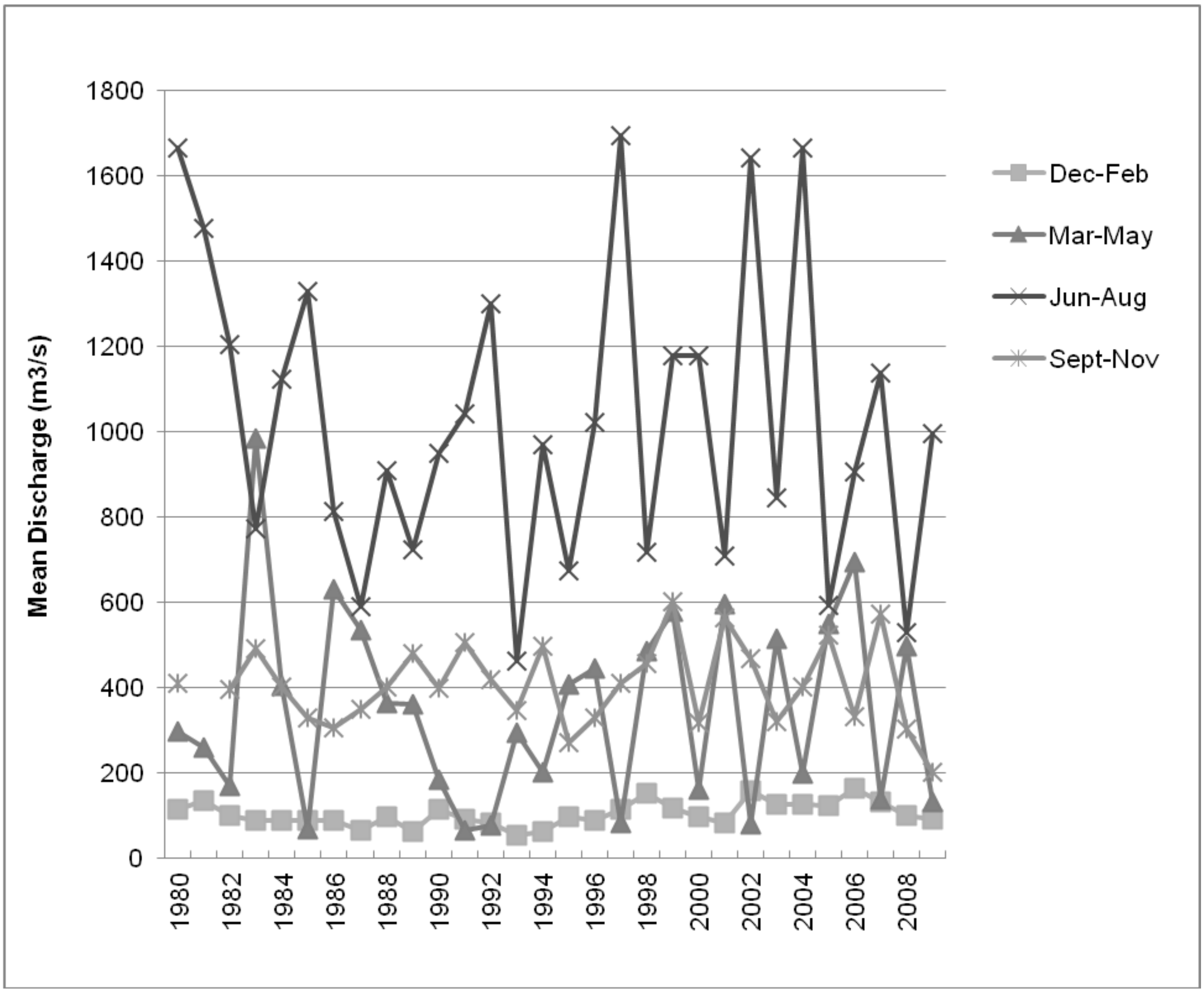
Drinking water sources in Nunatsiavut communities include chlorinated tap water, store-bought water and water gathered from running brooks, lakes, ice-melt, and other sources on the land. Study participants referred to water gathered locally as 'water on the land' in Rigolet and 'fetched water' or 'freshwater' in Nain. In this section of the paper study findings are presented alongside supporting literature, starting with access to, and availability and quality of, drinking water for each source and followed by preferences of drinking water and perceptions of study participants. First, watershed characteristics for the MWS in Rigolet and Nain are briefly described.

Watershed characteristics

The availability of water gathered from the land or recharging the MWS in Nain and Rigolet is subject to seasonal and inter-annual fluctuations and longer-term trends shaped by climate characteristics of the region. The community of Nain is situated on the boundary of Tikkoatokuk Bay and Kogaluk/Notakwanon watersheds. The research team was unable to locate a map depicting watershed boundaries at an adequate scale to discern which watershed supplies the community or whether it is fed by both catchments. There are no hydrometric stations located in the Tikkoatokuk Bay watershed and only one in the Kogaluk/Notakwanon watershed. Discharge records for this station show strong seasonal differences with maximum flow experienced in the snowmelt season from June to August and minimum flow in the winter months from December to February (Figure 4).

Rigolet is situated within the Hamilton Inlet watershed fed by the Naskaupi and Churchill rivers. While there are no hydrometric stations located within the watershed, discharge records for the Naskaupi River show strong seasonal differences similar to those illustrated by the Ugjoktok River near Nain. Maximum flow is experienced between June and August when the river is supplied by snowmelt and summer precipitation, and minimum flow occurs from December to February (Figure 5).

Figure 4. Seasonal discharge for Ugjoktok River below Harp Lake (Hydrometric station 03NF001).

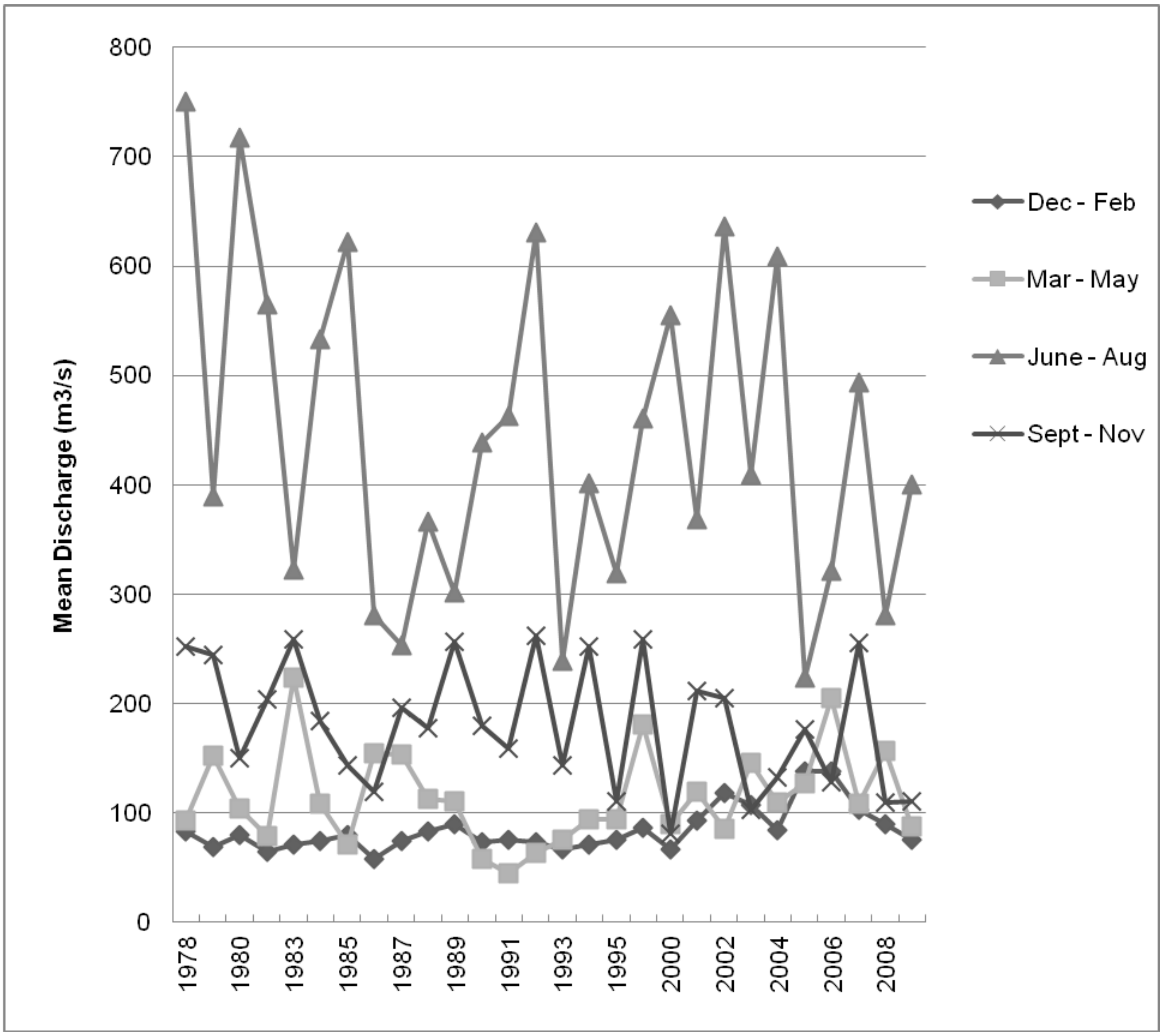


Source: Environment Canada, 2010. Data are missing for June-August 1981. The coordinates of the station are 55°14'2"N, 61°18'6"W.

Thirty-year discharge records for both monitored rivers show strong inter-annual and interdecadal variability in all seasons and particularly dramatic variability in the higher discharge seasons of summer and fall.

Goldhar et al. (in press) described observations by Rigolet residents of declines in the seasonal availability of water within the Hamilton Inlet watershed, commencing within the last thirty years. Specifically, residents noted a decrease in summer water levels and described the negative impact of these changes on their ability to hunt and harvest foods and gather drinking water from the land. Of the participating households in Rigolet 43% noted decreasing water levels in the region, while 34% noted no change and 24% were uncertain (ibid). Similar findings emerged in Nain where 48% of households observed declining water levels in the region, while 52% noted no change. Nain participants appeared to be affected less severely by observed changes compared to Rigolet residents and described an abundance of fresh water during all seasons, despite lowered water levels. Communities of Labrador et al. (2005) also documented a gradual drying trend and decrease in the seasonal availability of fresh water over the past forty to fifty years in Nunatsiavut, with accelerated change since the 1990s.

Figure 5. Seasonal discharge for Naskaupi River below Naskaupi Lake (Hydrometric station 03PB002).



Source*:* Environment Canada, 2010. Data were unavailable for 1981 and 1996-1998. The coordinates of the station are 54°7'54" N, 61°25'36" W.

Sources of community drinking water

Water gathered from the land

Nunatsiavummiut (Nunatsiavut Inuit) have gathered water and ice from the land and the sea for generations. Water is typically gathered in plastic buckets from sources surrounding the community and carried back home on foot or by a snowmobile, all-terrain vehicle (ATV) or other vehicle. Residents without the necessary vehicle are restricted in their access to water (for example, snowmobile owners can only access water in winter, while ATV owners may collect water in spring, summer and fall). As the practice of gathering water is physically demanding, elders noted an inability to collect water on their own and typically relied on family or friends to fetch water for them. In addition, residents without access to a vehicle or money to cover fuel costs noted having difficulty collecting water. Physical health and access to transportation either through household capital or social bonds are therefore important factors determining the ability of residents to gather water from the land.

The literature on drinking water in the region is relatively limited, though two studies addressing water quality have monitored the presence of total coliforms and *E. coli* in untreated water samples (Martin et al., 2007; Harper et al., 2011). Harper et al. (2011) found a significant positive association between bacteria in fetched water and run-off volume in Nain from 2007 to 2008. Their findings suggested a higher risk of infectious gastrointestinal illness stemming from the consumption of untreated surface water during spring and summer when run-off was at its peak.

In a study conducted in Nunavik, Martin et al. (2007) tested samples of raw water gathered from collection sites of drinking water and household storage containers in the communities of Umiujaq, Puvirnituq, Ivujivik and Kangiqsujuaq. Water analysed from the storage containers was more highly contaminated than raw water sources. Martin et al. (2007) recommended systematic environmental monitoring of the collection sites of drinking water and an educational campaign aimed at "raising residents' awareness of the risks associated with raw water consumption". Harper et al. (2011) and Martin et al. (2007) drew attention to the human health risk of consuming untreated water and the possible amplification of this risk in the future due to projected climate changes.

Tap water

As a remote, sparsely populated region, Nunatsiavut has a relatively recent history in the provision of tap water. The construction of the MWS in Nain and Rigolet was initiated by the Province of Newfoundland and Labrador in the late 1970s and development is ongoing with the construction of new housing units. Residents are responsible for the cost of connecting their homes to the main water line and not all homes in Nain are presently serviced by the MWS. Some other homes have no running water due to inability to pay for the cost of fixing previously frozen pipes, or to pay municipal utility taxes and electricity bills. An outdoor community tap in Nain, known as the 'water fountain', provides chlorinated water to these residents, though it is prone to freezing in winter. All homes are connected to the MWS in Rigolet.

Consumption levels are raised in both communities during winter months due to 'system bleeding', whereby residents are encouraged to maintain a constant flow of water running through their taps, and town maintenance workers systematically flush the main lines to prevent freezing. Freezing of the lines in Nain commonly leads to cracking and leaks, increasing the turbidity of water, necessitating additional chlorine to be added to the distribution system.

A similar need for additional chlorine is present in the Rigolet system in response to high levels of organic matter in the water supply, leading to the production of excess trihalomethanes (THMs). THMs are disinfection by-products from the chlorination process that are produced through the reaction of chlorine with organic compounds found in untreated water sources. Studies have shown positive associations between exposure to THMs, such as chloroform, and cancer (Morris et al., 1992; Mills et al., 1998), as well as reproductive and developmental effects (Reif et al., 1996; Mills et al., 1998; Dodds et al., 1999). Although unequivocal causation has yet to be demonstrated, in the interest of prudence, and following toxicological studies showing the carcinogenic effects of chloroform in rodents (National Cancer Institute, 1976), Health Canada established its first set of drinking water guidelines limiting THM consumption to 350 parts per billion in 1978 (Driedger and Eyles, 2003). This guideline was modified in 1993 to reflect the US guideline of 100 ppb. THM concentrations in Rigolet tap water averaged 208 ppb in 2008 (108 ppb above national drinking water guidelines) according to a draft report of a THM reduction study commissioned by the province (Noseworthy, 2008).[5]

In addition, boil water advisories (BWAs) frequently affect the MWS of both Nain and Rigolet. Two advisories lasting a total of 22 days each were issued in Nain from September 2009 to August 2010,

[5] A final report has yet to be issued.

while three were issued in Rigolet lasting a total of 95 days during a similar twelve-month period.[6] This is more than the average number of 1.5 BWAs per year in the province (Department of Environment and Conservation, 2009). Four of these five BWAs were the result of maintenance and repairs to the water distribution system.

Store-bought water

Store-bought water has been available in Nain and Rigolet since the late 1990s. Tap water filtered through a reverse-osmosis system is sold in refillable bottles and various brands of bottled water are shipped into the communities in summer and flown in during winter along with most other goods. The availability of bottled water is primarily determined by the ability of store-owners to successfully anticipate demand when placing stocking orders and the frequency of 'fair-weather' flights into the communities in winter. Weather conditions therefore directly influence the availability of bottled water in winter months.

The cost of bottled water is prohibitively expensive for the majority of households in Nain and Rigolet, and these costs are increased in winter when supply is limited and the additional costs of flight transportation are added. Residents of Rigolet noted spending up to 30 dollars for a case of 12, 500 ml bottles of water in winter 2009 (more than 200% the summer price) due to short supply in the community. Filtered tap water sold in bottles that may be refilled by the consumer sell for roughly 15% of the price of bottled water in both communities (when purchased in 18.8 L volumes), though their sale is prohibited during BWAs. As a result of unaffordable bottled water prices, households in Rigolet travel by boat down the coast to Happy Valley-Goose Bay (about 160 km over water) during ice-free seasons to stock up a variety of supplies including bottled water, thus augmenting the availability of goods in the community. No similar practices were noted in Nain, probably due to the long distance between the community and larger population centres such as Happy Valley-Goose Bay (about 580 km over water to Happy Valley-Goose Bay).

Drinking water preferences and perceptions: Desirability of drinking water sources

Sources of drinking water available in Nain and Rigolet are each viewed as unique and are used to varying degrees by study participants. To more effectively illustrate these points, participant quotes have been used in this section to communicate residents' perspectives through their own words. Quotes were selected that typify responses from the broader sample.

Tap water was the least favourable source of drinking water available to residents of Rigolet and Nain and was commonly described in negative terms by participants from both communities (Table 3). For the majority of Nunatsiavut residents, expectations of how 'ideal' drinking water should taste, look and smell are shaped by experiences of water consumption on the land. Tap water is evaluated through subjective comparisons with the organoleptics of land-sourced water. The description of water on the land as 'real', 'natural', and 'just water' further suggests that store-bought and tap water are compared to water from the land. Illustrating a preference for non-tap water alternatives, Jake stated: "If I have a choice, tap water would be my last choice". Sarah noted: "It smells gross. Tastes, I don't know. I won't drink it out of the tap. The colour is brown".

Dissatisfaction with the taste and smell of chlorine, and additional aesthetic characteristics such as colours ranging from yellow in summer to dark brown in spring, and a 'groundy' (earthy) taste more common in spring, were all noted as factors dissuading potential tap water drinkers. Taste perceptions

[6] This accounts for all BWAs archived by the Rigolet Inuit Community Government and the Nain Inuit Community Government. At the time of accessing these records some staff in Nain expressed doubt that the two advisories noted were an accurate representation of all BWAs experienced by the community in the previous 12 months.

of tap water additives, such as chlorine, are heightened when returning to the community after a trip on the land when non-chlorinated sources were consumed.

"The town water is chlorinated, there's chlorine in it and you can taste it. You can smell it when you have a bath, when you have a cup of tea. Especially when you come back from off the land, even for a weekend. If you're drinking water from out of the brooks and you come back you can hardly drink it" (Jake, from Rigolet).

A greater portion of Rigolet respondents indicated that they primarily consume store-bought water in the community (47% in Rigolet, 6% in Nain; Table 4). This divergence may be accounted for by the increased affordability and availability of store-bought water for Rigolet residents due to the proximity of the community to Happy Valley-Goose Bay.

While the cost of bottled water restricts its access for most community members, interview discussions revealed that personal preference rather than cost is the primary factor dissuading residents. Similar to tap water, store-bought water was commonly described in negative terms that signify potential health concerns and was contrasted with Nature and 'the natural'. Words such as 'plastic', 'stale', and 'dead' distinguished store-bought water from the 'fresh', 'pure', 'alive', and 'natural' water gathered from the land. The use of words such as 'dead' and 'alive' may imply water on the land is imbued with meaning that extends beyond its physical properties and forms in the minds of residents, and that these qualities are absent in tap water and store-bought water.

Table 3. Household perceptions of drinking water attributes in Rigolet and Nain.

Question	Community	Tap water	Store-bought water	Water on the land
How would you describe the colour, taste and smell of your water?	Nain (n=33)	Chlorine, stale, discoloured, metal, brown, not bad	Flat, plastic, no colour, no taste, no smell, unpleasant, stale	Fresh, pure, clear, no taste, no smell, real, cleaner, brown, healthy
	Rigolet (n=89)	Brown, cloudy, chemical, Javex, groundy	White, clear, nothing, dead, plasticky, saline	Alive, white, just water, brown, clear, groundy, natural

Perceptions of risks of drinking water

When asked directly, resident perceptions of the safety of tap water relative to water gathered from the land differed considerably in both communities (Table 5). Households indicating water from the land was 'sometimes' safe highlighted the importance of avoiding brooks with raised water levels and high sediment content due to excess rain or spring thaw. Techniques used by residents to ensure adequate quality of drinking water on the land include: observing weather patterns and water levels, straining water through a cloth to reduce turbidity, and sensory inspection of the water to evaluate its colour, opaqueness, taste and smell. Additionally, residents expressed a preference for familiar water sources accessed in the past, and running water or water gathered from a source with a clear inflow and outflow, thus avoiding the consumption of stagnant water. Matilda stated: "I trust nature and the natural environment around here. It's the same brook that my mom and dad drank out of, my grandfather and my grandmother drank out of, and my grandfather lived to be ninety-five".

Table 4. Drinking water source preferences and use in Nain and Rigolet. Percentages may not add to 100% due to rounding and alternative responses.

Question	Community	Tap (%)	Store-bought water (%)	Water on the land (%)
1. What is your favourite source of drinking water?	Nain (n=32)	0	9	91
	Rigolet (n=89)	6	17	78
	aggregate (n=121)	4	15	81
2. What is your primary source of drinking water in the community?	Nain (n=33)	58	6	36
	Rigolet (n=89)	36	47	17
	aggregate (n=122)	42	36	22
3. What is your primary source of drinking water on the land?	Nain (n=33)	0	0	97
	Rigolet (n=89)	2	10	78
	aggregate (n=121)	2	7	84

While aesthetic characteristics of water play a role in informing the confidence of residents, the broader environment from which the source is accessed at the time it is accessed is also important. The suitability of a water source for drinking purposes is regarded as variable, and 'white', 'clear-looking' brook water may be avoided if the immediate environment of the source presents cause for concern. Two households in the Rigolet study provided examples to illustrate these considerations; the first described finding scat from a wolf (*amaruk*) near where they usually collect brook water, and the second described finding a dead caribou (*tuktuk*). Both households moved further upstream to collect water at that time. As water on the land is gathered directly from its source, residents have a more intimate awareness of factors contributing to the suitability of drinking water than of drinking tap water. They are drawing on individual, household, and community experiential knowledge and deciding for themselves which sources are appropriate for drinking, rather than placing trust in municipal water workers, health authorities and the technologies of the municipal water system.

For both Nain and Rigolet, respondents who stated their tap water was 'sometimes' safe noted seasonal changes in tap water organoleptics, the presence of BWAs in the community and fluctuations in perceivable chlorine levels. For these residents, the chlorination of drinking water not only resulted in negative organoleptics, but also diminished public trust in tap water due to fears regarding negative health outcomes associated with chlorine consumption. In Rigolet these fears were exacerbated due to knowledge of excessive THM concentrations in their tap water. Highlighting these fears, Cindy stated: "[t]he worst thing I find are the THMs, I keep thinking about them. When they started talking about that we started buying water at the store".

Table 5. Perceptions of the safety of drinking water in Nain and Rigolet. (Percentages may not add up to 100% due to rounding off and alternative responses.)

Question	Community	Yes (%)	No (%)	Sometimes (%)	Unsure (%)
1. Do you feel your tap water is safe to drink?	Nain (n=32)	53	16	13	19
	Rigolet (n=86)	41	37	12	11
	Aggregate (n=118)	45	31	12	13
2. Do you feel water gathered from the land is safe to drink?	Nain (n=32)	75	0	25	0
	Rigolet (n=86)	57	4	27	13
	Aggregate (n=118)	62	3	26	9

In addition to the treatment of municipal water, knowledge of the multiple uses of the community tap water source, both historically and currently, shapes the perception of the risk of tap water. In Rigolet, residents expressed concern regarding the use of the Rigolet Pond for recreational purposes, such as swimming in summer, and skating and snowmobiling in winter. Before the airport was built, the frozen pond was used to land planes in winter, and dogsleds were mushed on the ice before snowmobile use was widespread. Respondents also expressed fears that the Rigolet Pond was contaminated when the Canadian Army was stationed in Rigolet during the Second World War.[7]

DISCUSSION

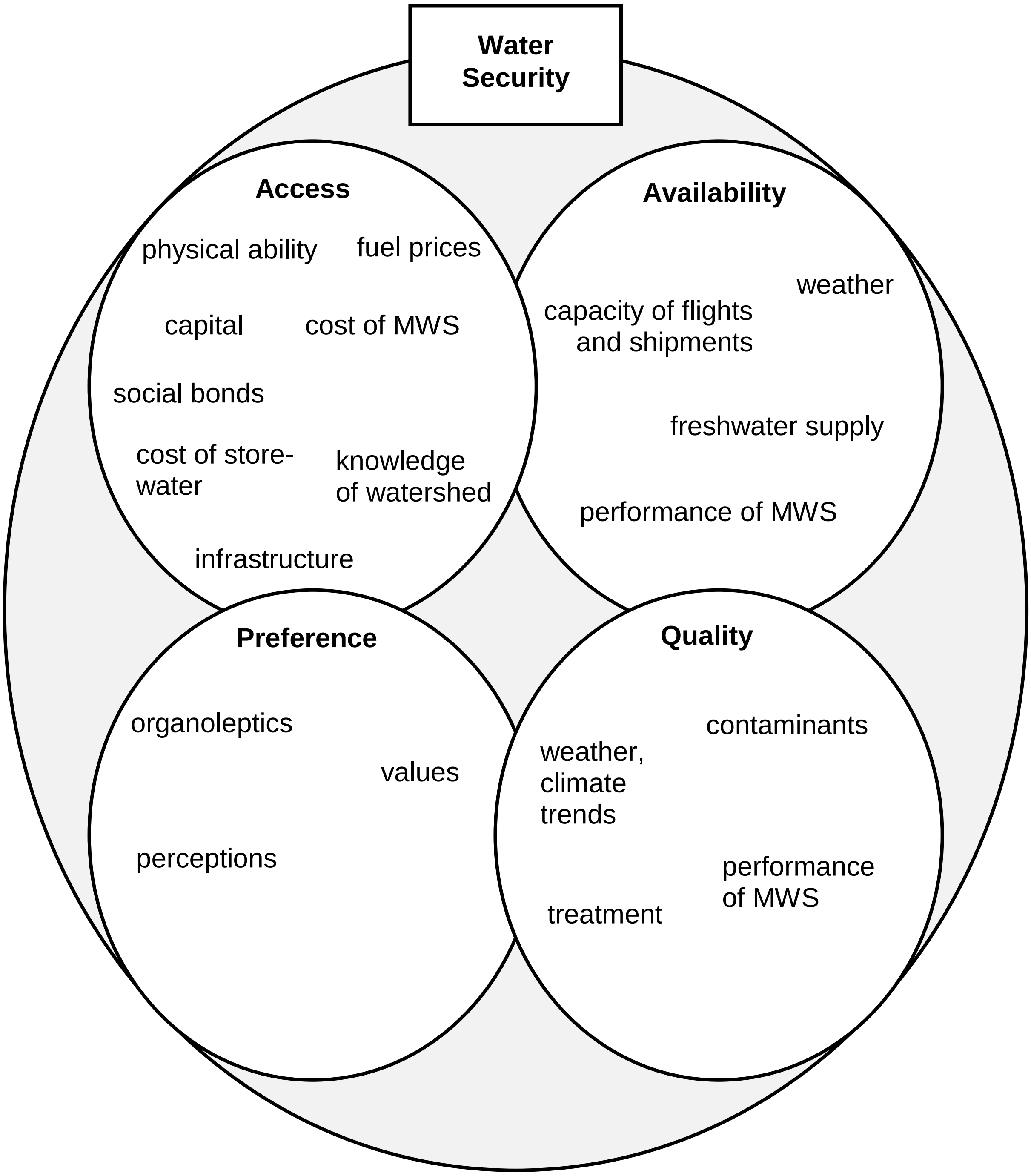
Gathering water and ice for drinking is a practice deeply rooted in the history of water consumption in Nunatsiavut. These practices have been continued to the present, despite the introduction of alternative drinking water sources in recent years that arguably offer greater convenience. The reasons for the continuation of these practices extend beyond arguments of historic precedence alone, as has been discussed in previous sections. Preferences of drinking water sources are also shaped by organoleptics and risk perceptions. Access and availability restrictions determine whether preferred water sources are consumed and, if so, to what extent.

Findings from the Rigolet and Nain case studies indicate that access to a sufficient quantity of desirable, clean drinking water is compromised for some residents. By way of summary, Figure 6 illustrates some of the dimensions of access to, and availability, preference, and quality of, drinking water contributing to water security in Nain and Rigolet. These dimensions were found to be dynamic and intimately linked. Individual and household cash resources, transportation, social bonds, the price of fuel and water, and the availability of store-bought water have influenced access to water in both communities. Store-bought water availability was shaped by short-term weather conditions, long-term climate trends, the freight capacity of flights and shipments into the community, and the ability of

[7] Several hundred Canadian soldiers were stationed in Rigolet from roughly 1943 to 1945 "to protect the inland waterway of Lake Melville and access to the Happy Valley-Goose Bay air base" (Knight and Associates, 2005).

store-owners to successfully predict consumer demand, in addition to the ability of residents to travel to other communities, such as Happy Valley-Goose Bay to purchase auxiliary supplies. Elders and others with limited physical abilities, households with minimal income and capital, newcomers to the community, and others without well-developed social networks or knowledge of the region have experienced additional challenges to their water security.

Figure 6. Factors contributing to water security in Rigolet and Nain.



Residents' preference for drinking water gathered from the land and store-bought water over chlorinated tap water is not surprising considering the physical qualities of tap water in both communities. Physical properties of tap water differ relative to the qualities of the untreated water source, and collection, distribution and treatment methods in the MWS. In Rigolet and Nain these properties have led to frequent BWAs and necessitated the additional use of chlorine to maintain a satisfactory free chlorine residual level throughout the distribution system; for Rigolet this additional chlorine may contribute to the production of excessive THMs. Engineering challenges such as permafrost, cold temperatures, community isolation, and minimal local resource capacity all contribute to the performance of the MWS, tap water characteristics, preferences and perceptions of drinking water, and ultimately the water security of residents.

Many participants of the study in Nain and Rigolet regard the physical quality of their tap water as sub-standard (31% feel their tap water is not "safe to drink") and the majority (81%) have preferences for drinking water sourced from the land. These findings are consistent with studies on perception of drinking water conducted on the Seward Peninsula of Alaska. In a study of the communities of Shishmaref and White Mountain, Marino et al. (2009) found that cold, remote locations presented a variety of engineering challenges for the installation and maintenance of centralised drinking water systems that are difficult and expensive to address. Consequently, the physical attributes of tap water (such as the colour, taste, smell and turbidity) may be less desirable than drinking water from alternative sources available to the community. These characteristics have contributed to personal preferences for water gathered from the land and the perception that treated water may pose a potential health threat (Marino et al., 2009).

Among other variables, poor infrastructure and a need for greater technological investments have been identified as a determinant of water security and water- related vulnerabilities in aboriginal communities in Canada and across the globe (Vörösmarty et al., 2010; von der Porten and de Loë, 2013). While investment in drinking water system infrastructure is certainly indispensable, findings from case studies in Nain and Rigolet emphasise the importance of providing locally adapted solutions for drinking water. Aboriginal communities across Canada suffer from exceptionally poor quality drinking water, often despite the presence of centralised water systems (Walken, 2006; Marino et al., 2009; Phare, 2009; de Loë and Plummer, 2010; Simeone, 2010; Cave et al., 2013; von der Porten and de Loë, 2013). The installation of these systems does not ensure drinking water improvements if the technologies applied are generically designed and not suited to the attributes of the untreated water source entering the system and other climatic and environmental characteristics of the locality. A failure to adequately address the attributes of the local environment when designing technological solutions may lead to the production of tap water that is undesirable to residents, and ultimately of limited use.

While some parallels may be drawn when considering challenges to drinking water across communities, the dynamics of a community drinking water system, including all sources available to residents, shape the water security of that community. As demonstrated through findings from Nain and Rigolet, in addition to access, availability and quality, preferences of drinking water play a large role in determining water security. Each of the water sources is regarded as distinct and is imbued with significance and a history of meaning and tradition that may shape contemporary uses. It is thus important to note that understanding water security includes considering a variety of possible primary drinking water sources (including 'untreated' sources in the case of Rigolet and Nain).

CONCLUSIONS

Changes in availability of fresh water that may be connected with climate variability and change are exacerbating existing water security stresses in Nunatsiavut. Residents of Nain have described declining water levels in surrounding watersheds, while Goldhar et al. (in press) have documented significant changes in fresh water noted by Rigolet residents within the last thirty years, affecting the availability and accessibility of preferred drinking water sources, food sources, and subsistence livelihoods. Future climate variability and change will likely have significant repercussions for freshwater ecosystems in northern high latitude environments, altering habitat for aquatic wildlife and influencing community-dependent water resources (Wrona et al., 2006; Bates et al., 2008; Vincent and Laybourn-Perry, 2008). Current trends in availability of fresh water described by residents of Labrador may continue in the future. Projections indicate reductions in streamflow by 2050 due to increases in evaporation and transpiration, despite projected increases in precipitation by 10-20% (Jacobs and Bell, 2008). The seasonal variability of future climate and stream discharge will greatly shape the experience of these changes for residents of Nunatsiavut, and the possible effects they may have on water security and other measurements of well-being in the region.

As demonstrated through the Nain and Rigolet case studies presented in this paper, diverse geographies of people and place produce diverse attributes of drinking water systems and should inform approaches to understanding water security. In assessing use of tap water systems by residents we need to consider data contextualising the attributes of community drinking water systems, drinking water preferences, perceptions, and the myriad factors shaping these perspectives. Many challenges are met when constructing infrastructure for water systems in remote communities in cold climates. A failure to adequately adapt technologies to meet the demands of a local environment may result in drinking water that is undesirable to users. While centralised drinking water systems and investments in infrastructure may improve the quality and security of water in remote communities, these efforts are of limited value if the tap water produced in these systems is not consumed.

In addition to knowledge of the local environment, a knowledge of all sources of drinking water available to residents, drinking water preferences and perceptions of drinking water is needed to develop successful water security strategies. Solutions for problems in drinking water must be compatible with the preferences, values, knowledge systems and worlds of residents. In the interest of water security, we need to consider how the accessibility, availability and quality of all drinking water sources (and preferred sources in particular) can be improved, as illustrated by the water security approach presented above.

The concept of a drinking water system presented in this paper provides a lens through which to view water security, grounding approaches within the contextual attributes of a community and locality. This conceptualisation emphasises drinking water availability, quality, access and preference. By not presuming which water sources are desirable to users, this framework has attempted to create space for the inclusion of water knowledges and preferences existing outside the norms of the dominant water security discourse. As climate variability and change continue to modify the spatial and temporal distribution of drinking water sources in the Arctic, it has become increasingly important to identify and understand factors contributing to the water security of Arctic residents. An awareness of drinking water access, availability, quality, and preferences, is needed to produce thoughtful, sensitive and relevant water security research and policy in the Arctic.

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